THIS IS A CONTINUATION OF INTERNATIONAL APPLICATION PCT/EP00/08649, WITH INTERNATIONAL FILING DATE OF SEPTEMBER 5, 2000, CLAIMING PRIORITY OF GERMAN PATENT APPLICATION 199 42 398.9, FILED SEPTEMBER 6, 1999.

Method of Storing Solar Energy

Technical Subject

The invention relates to a method of storing solar energy in conjunction with reducing the CO_2 content of air.

During the generation of energy from fossile fuels, CO_2 is released into the atmosphere in considerable amounts. According to presently valid climate models, there occurs thus a rise in the CO_2 content of the atmosphere. This rise produces a "greenhouse effect" and thereby a rise in the mean global temperature which, in turn, may result in serious climate changes. Therefore, efforts are made to reduce the CO_2 emission.

State of the Art

The reduction in the CO_2 emission is attempted to be achieved in different ways. One way entails saving energy by improving the insulation of buildings, by increasing the efficiency of heat engines and so forth. In this manner, the still required energy is predominantly generated by using fossile fuels whereby CO_2 is still further released. Another way of generating energy comprises the use of "solar energy". This encompasses energy which is directly generated by insolation, i.e. by means of solar cells or solar collectors. Also, in this group other energies may be included which are indirectly produced by insolation such as wind energy and water energy. Solar, wind and water energies, however, are accompanied by environmental impacts in the event that high power is intended to be generated. While these types of energy are neutral with respect to the release of CO_2 and do not increase the CO_2 content of the atmosphere, they nevertheless do not reduce the CO_2 content.

Finally, there still exists the generation of energy from biomass. The most common way is heating by means of wood or charcoal. However, it is also known to produce hydrogen or alcohol from biomass. Also these energies are neutral with respect to the release of CO_2.

The CO_2 which is released by the combustion of wood has been removed from the atmosphere prior thereto by photosynthesis.

All these known measures are neutral with respect to the release of CO_2 in the favourable case. These measures cannot reduce the present CO_2 content of the atmosphere or compensate for the CO_2 originating from other sources.

Disclosure of the Invention

The invention is based on the object of providing a method of producing and storing energy from solar energy while simultaneously effecting a reduction in the CO_2 content of the air.

The method according to the invention comprises the following method steps:

(a) providing an amount of biomass which has been formed by photosynthesis and which is suitable for forming charcoal;
(b) converting the amount of biomass into charcoal;
(c) permanently storing a substantial fraction of the charcoal; and
(d) converting only the remaining portion of the charcoal into energy or an energy source.

The amount of photosynthetic biomass such as wood has removed CO_2 from the atmosphere and thus reduced the CO_2 content in the atmosphere. When this biomass now is converted into charcoal, then, a storable material is obtained which, when appropriately stored, does not rot with the generation of greenhouse gases. Thus, when a substantial amount of the charcoal is permanently stored, a corresponding amount of CO_2 is sustainably removed from the atmosphere.

The remaining fraction may be converted in known manner into energy or an energy source like heat, electricity or hydrogen. The land, on which the plant biomass had been

generated prior to the conversion into charcoal, may be replanted in suitable manner and thus be used again for producing photosynthetic biomass and charcoal therefrom.

Description of Preferred Embodiments

Example 1: Charcoal, which has been produced from photosynthetic biomass in known manner, is stored in a bunker plant. For this purpose, the charcoal is infed into the bunker plant and outfed therefrom upon request by using technically conventional conveying means. For example, subterraneous cavities such as present in a coal, ore or salt mine or the like as well as known above-ground constructions are considered for such bunker plants. The charcoal storage is intended for time periods of up to 20 years or more. In order to prevent ignition or oxidative degradation, the charcoal is stored under non-ignitable protective gas having a density greater than air such as CO_2 or, if desired, a rare gas. Each bunker plant is equipped with known means in a manner such that the stored charcoal is protected from water ingress and/or excess temperatures. A number of mutually separate charcoal reservoirs may be provided in a given bunker plant.

Example 2: According to data published by the Bundesumweltamt (Federal Environment Office) 1,000 mio t of CO_2 were emitted in the Federal Republic of Germany in 1990. According to the Berlin and Kyoto treaties undertook to reduce the annual CO_2 emission by 25% in relation to the CO_2 emission of 1990, i.e. by 250 mio t p.a. until 2005. Until now, already a reduction by 17% was achieved by means of a series of measures and this reduction will have to be still further increased by 8% or 80 mio t p.a. until 2005. According to the CO_2 molecular weight of 44 and to the carbon atomic weight of 12, this CO_2 reduction by 80 mio t p.a. corresponds to an amount of 21.8 mio t carbon p.a. or, in terms of charcoal 89.2% of which consist of pure carbon, an amount of 24.4 mio t charcoal p.a..

In a publication entitled "Unser Wald" ("Our Forest") by the Bundesministerium für Ernährung, Landwirtschaft und Forsten (Federal Office of Food, Agriculture and Forestry) is stated on pages 41 and 42 that 57 mio m^3 of wood were produced in 1997 in the Federal Republic of Germany by means of sustained forestry. 38 mio t thereof were

harvested and supplied for consumption. This amount of commercially produced wood removes CO_2 contained the air; a large portion of this wood is further processed to yield wooden products and objects which are not subjected to combustion, while an other portion is burned with the formation of CO_2. The wood industry and forestry contribute to the CO_2 content of the air according to this relationship. In correspondence therewith, the CO_2 content of the air can be reduced if either (a) wood production is increased whereby more CO_2 is removed, and/or (b) production of CO_2 by wood combustion is reduced, whereby the additionally produced wood and/or the non-burned wood is converted into charcoal and stored in accordance with Example 1. The conversion into charcoal has the added advantage that during this process valuable side products such as acetic acid and homologues thereof, methanol and acetone are produced and thus are obtained in desired manner from renewable resources and not from fossile sources.

The energy content of fuels is frequently given in Steinkohleeinheiten SKE (Coal Units); this unit corresponds to the average energy contant of 1 kg coal having an average carbon content of 0.8923 kg. According to Römpps Chemie Lexikon (Römpps Encyclopedia of Chemistry) 1983, p. 3968, 1 kg SKE equals 8.141 kWh and corresponds to 1.9 kg of wood which thus also contain 0.8923 kg of carbon. At an average wood specific density of 0.66 g/cm^3 (Römpps Chemie Lexikon 1983, p. 1733, l.-h. column) which corresponds to 0.66 t/m^3, 1 m^3 of wood thus contains 0.31 t of carbon which corresponds to the removal of 1.14 t of atmospheric CO_2. If now, according to the aforecited undertaking, 80 mio t CO_2 p.a. are intended to be bound in the form of wood and to be stored in the form of 24.4 mio t p.a. of charcoal, then, an additional production of 37 mio m^3 of wood would be required by sustainable forestry; this amount could still be reduced to the extent in which the combustion of wood for the generation of energy could be restricted. Such additional sustainable wood production appears entirely feasible considering that (1) according to the aforementioned publication "Unser Wald" ("Our Forest") only 38 mio m^3 of the 57 mio m^3 of wood, which were produced in 1997, were utilized and (2) a production increase by a factor of 2 to 3 is considered possible by the experts. The additional sustainable wood production of 37 mio t may also be conducted until Jan. 1, 2005, in a manner such that the wood production is increased by 9.25 mio t p.a. and the stored amounts of charcoal are increased by 6 1 mio t each year.

Example 3: A minor portion of the charcoal produced or stored according to Examples 1 or 2, for example, 25%, is reacted with water to form hydrogen which not only represents a very high-energy fuel but particularly also produces the combustion product water which is totally harmless with respect to the environment or atmosphere.
The reaction of carbon and water according to the equation of reaction

$$C + 2\,H_2O = CO_2 + 2\,H_2,$$

however, is more complicated:

In a technical pressure reactor, there occurs first a highly endothermic carbon gasification according to

$$(1) \quad C + H_2O = CO + H_2$$

only at very high temperatures, which is followed at only moderately increased temperatures by the weakly endothermic "water gas shift reaction"

$$(2) \quad CO + H_2O = CO_2 + H_2.$$

In order to achieve the required temperatures above 1500°C at the input of the pressure reactor for the coal gasification (1), a required amount of oxygen admixed to the reactants water and finely divided carbon. There thus remain still about 83.4% of the coal to be processed for the production of hydrogen.

A typical Texaco plant for coal gasification (Kirk-Othmer, ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY 3rd Ed. Vol. 12, Wiley, New York, pp. 959/960) having a capacity of 2.83×10^6 m^3/d of raw hydrogenis charged with 1,852 t/d of finely divided charcoal (of which 83.4% are process charcoal). Compared to all fossile coals, charcoal has the advantage of being free of any sulfur and heavy metal catalyst poisons whereby the useful life of the catalysts is prolonged and their efficiency is improved while special gas purification operations become superfluous.

A typical Texaco plant processing 1,852 t/d or 0.676 mio t p.a. of charcoal is confronted with 25% or 6.1 mio t p.a. of charcoal originating from storage in 2005 whereby 9 such

plants can be operated. Sizable storage of the charcoal thus may be the foundation of the reliability of the logistics for the solar hydrogen economy.

The stored charcoal can be accessed for hydrogen production at any desired time because the main amount thereof must remain stored for sustained energy provision by reversing combustion.

According to the reactions (1) and (2), there are produced hydrogen and CO_2. The thus generated amount of CO_2 corresponds to the amount which has been removed from the atmosphere before and which has been bound in the photosynthetic biomass of wood. The thus generated amount of CO_2 is thus balanced by the corresponding amount of photosynthetic biomass which has been formed. The thus produced hydrogen substitutes other fuels, particularly fuels originating from fossile sources, which form CO_2 on combustion, and preferably serves for generating energy by means of fuel cells.

The reaction may also be conducted such that the synthesis gas, which is obtained by reaction (1), is reacted by known, particularly catalytic processes to form industrial products for use in many technical fields. Thus, these products are also obtained from renewable resources without requiring recourse to fossile raw materials like crude oil, natural gas or coal.